CLAIMS

1. A method for multi-user detection, comprising:

receiving a complex input signal due to a superposition of waveforms encoding symbols in a real-valued constellation, which are transmitted respectively by a plurality of transmitters in a common frequency band;

sampling the complex input signal at sampling intervals over the duration of an observation period to provide a sequence of complex samples;

processing the sequence of complex samples to determine soft decision values corresponding to the symbols transmitted by the plurality of the transmitters in the observation period, while constraining the soft decision values to be real values; and

projecting the soft decision values onto the constellation to estimate the transmitted symbols.

2. A method according to claim 1, wherein the waveforms comprise code-division multiple access (CDMA) waveforms transmitted by the plurality of the transmitters, and wherein the symbols transmitted by the transmitters are modulated by respective spreading codes to generate the waveforms.

3. A method according to claim 2, wherein the spreading codes comprise complex-valued codes.

4. A method according to claim 1, wherein the constellation of the symbols consists of the values +1 and -1.

5. A method according to claim 4, wherein projecting the soft decision values comprises taking respective

signs of the soft decision values in order to reach a hard decision with respect to the corresponding symbols.

6. A method according to claim 1, wherein the observation period has a duration substantially equal to a single symbol period, during which each of the transmitters transmits a single one of the symbols.

7. A method according to claim 1, wherein the observation period has a duration during which at least some of the transmitters transmit more than a single one of the symbols.

8. A method according to claim 1, wherein processing the sequence of complex samples comprises partitioning the samples into real and imaginary parts, and processing the real and imaginary parts separately to determine the soft decision values.

9. A method according to claim 8, wherein the real and imaginary parts of the samples are related to the transmitted symbols by an expression having a form $\bar{\mathbf{x}} = \bar{\mathbf{S}}\mathbf{b} + \bar{\mathbf{n}}$,

wherein $\bar{\mathbf{x}}$ is a vector comprising real vector elements corresponding separately to the real and imaginary parts of the samples, $\mathbf{b}$ is a vector comprising real vector elements corresponding to the values of the symbols, $\bar{\mathbf{S}}$ is a matrix comprising columns corresponding to respective complex signatures of the plurality of the transmitter, the columns comprising real entries corresponding separately to the real and imaginary parts of the signatures, and $\bar{\mathbf{n}}$ is a vector comprising real vector elements corresponding separately to real and imaginary noise components in the samples, and

wherein processing the sequence of complex samples comprises inverting the expression to determine the soft decision values of the elements of **b**.

10. A method according to claim 9, wherein inverting the expression comprises finding the real values of the elements of **b** that minimize a norm given by $\left\|\bar{\mathbf{x}} - \bar{\mathbf{S}}\mathbf{b}\right\|^2$.

11. A method according to claim 10, wherein finding the real values of the elements of **b** comprises calculating a vector $\tilde{\mathbf{b}}$ of the soft decision values so that $\tilde{\mathbf{b}} = \left(\bar{\mathbf{S}}^T\bar{\mathbf{S}}\right)^{-1}\bar{\mathbf{S}}^T\bar{\mathbf{x}}$.

12. A method according to claim 9, wherein inverting the expression comprises:

decomposing $\bar{\mathbf{S}}$ to yield an upper-triangular matrix **T** that satisfies an equation $\mathbf{z} = \mathbf{Tb} + \nu_1$, wherein **z** and ν_1 are vectors obtained by applying a unitary transformation to $\bar{\mathbf{x}}$ and $\bar{\mathbf{n}}$, respectively; and

finding the real values of the elements of **b** iteratively beginning from a final one of the elements so as to solve the equation.

13. A method according to claim 12, wherein processing the sequence of complex samples comprises ordering the elements of **b** in an ascending order of power of the waveforms transmitted respectively by the transmitters, and ordering the entries in $\bar{\mathbf{S}}$ according to the order of the elements in **b**, so that finding the real values iteratively comprises finding the real values beginning from one of the transmitters having a high power relative to the other transmitters.

14. A multi-user receiver, comprising:

input circuitry, coupled to receive a complex input signal due to a superposition of waveforms encoding symbols in a real-valued constellation, which are transmitted respectively by a plurality of transmitters in a common frequency band, and to sample the complex input signal at sampling intervals over the duration of an observation period to provide a sequence of complex samples; and

multi-user detection circuitry, coupled to receive and process the sequence of complex samples so as to determine soft decision values corresponding to the symbols transmitted by the plurality of the transmitters in the observation period, while constraining the soft decision values to be real values, and to project the soft decision values onto the constellation in order to estimate the transmitted symbols.

15. A receiver according to claim 14, wherein the waveforms comprise code-division multiple access (CDMA) waveforms transmitted by the plurality of the transmitters, and wherein the symbols transmitted by the transmitters are modulated by respective spreading codes to generate the waveforms.

16. A receiver according to claim 15, wherein the spreading codes comprise complex-valued codes.

17. A receiver according to claim 14, wherein the constellation of the symbols consists of the values +1 and -1.

18. A receiver according to claim 17, wherein the multi-user detection circuitry is arranged to take

respective signs of the soft decision values in order to reach a hard decision with respect to the corresponding symbols.

19. A receiver according to claim 14, wherein the observation period has a duration substantially equal to a single symbol period, during which each of the transmitters transmits a single one of the symbols.

20. A receiver according to claim 14, wherein the observation period has a duration during which at least some of the transmitters transmit more than a single one of the symbols.

21. A receiver according to claim 14, wherein the multi-user detection circuitry is arranged to partition the samples into real and imaginary parts, and to process the real and imaginary parts separately to determine the soft decision values.

22. A receiver according to claim 21, wherein the real and imaginary parts of the samples are related to the transmitted symbols by an expression having a form $\bar{\mathbf{x}} = \bar{\mathbf{S}}\mathbf{b} + \bar{\mathbf{n}}$,

wherein $\bar{\mathbf{x}}$ is a vector comprising real vector elements corresponding separately to the real and imaginary parts of the samples, $\mathbf{b}$ is a vector comprising real vector elements corresponding to the values of the symbols, $\bar{\mathbf{S}}$ is a matrix comprising columns corresponding to respective complex signatures of the plurality of the transmitter, the columns comprising real entries corresponding separately to the real and imaginary parts of the signatures, and $\bar{\mathbf{n}}$ is a vector comprising real

vector elements corresponding separately to real and imaginary noise components in the samples, and

wherein the multi-user detection circuitry is arranged to invert the expression to determine the soft decision values of the elements of **b**.

23. A receiver according to claim 22, wherein the multi-user detection circuitry is arranged to invert the expression by finding the real values of the elements of **b** that minimize a norm given by $\|\bar{\mathbf{x}} - \bar{\mathbf{S}}\mathbf{b}\|^2$.

24. A receiver according to claim 23, wherein the multi-user detection circuitry is arranged to find the real values of the elements of **b** by calculating a vector $\tilde{\mathbf{b}}$ of the soft decision values so that $\tilde{\mathbf{b}} = \left(\bar{\mathbf{S}}^T\bar{\mathbf{S}}\right)^{-1}\bar{\mathbf{S}}^T\bar{\mathbf{x}}$.

25. A receiver according to claim 22, wherein the multi-user detection circuitry is arranged to decompose $\bar{\mathbf{S}}$ to yield an upper-triangular matrix **T** that satisfies an equation $\mathbf{z} = \mathbf{T}\mathbf{b} + \nu_1$, wherein **z** and $\mathbf{v}_1$ are vectors obtained by applying a unitary transformation to $\bar{\mathbf{x}}$ and $\bar{\mathbf{n}}$, respectively, and to find the real values of the elements of **b** iteratively beginning from a final one of the elements so as to solve the equation.

26. A receiver according to claim 25, wherein the multi-user detection circuitry is arranged to order the elements of **b** in an ascending order of power of the waveforms transmitted respectively by the transmitters, and to order the entries in $\bar{\mathbf{S}}$ according to the order of the elements in **b**, so as to find the real values

iteratively beginning from one of the transmitters having a high power relative to the other transmitters.